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ABSTRACT

This paper was based on a study of the writings of six scientists for lay readers and discussions with the authors on their concepts of audience and audience adaptation. Scientists who write popular or literary essays use several devices and methods that allow the successful transference of technical or scientific information to a general audience. These techniques include focusing on an audience with little scientific background; never underestimating the readers' intelligence or overestimating their knowledge; using biography, autobiography, and personal anecdotes to add a human element; using personal pronouns; focusing on a specific, concrete example; using comparison and contrast; and using humor. Scientific writers hope that by using these devices they can change public opinion about science and scientists. Writings of the six science authors are listed in the bibliography. (EL)

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BRIDGING THE GAP: SCIENCE FOR A POPULAR AUDIENCE

When scientists write for a general audience, they must make significant changes in the way they write and conceive of their audience. Scientists are schooled in the appropriate ways to address the scientific community even if they recognize as Lewis Thomas said that it produces "absolutely hideous, hideous prose . . . [but] I was brought up by the Rockefeller Insititute, and I learned the rules of writing a scientific paper. I was unable to change them." However, many scientists when not writing for their academic peers forget these rules and use others to generate eminently readable essays for the general public.

After discussing the concept of audience and audience adaptation with six scientists (see bibliography) who write popular or literary scientific essays and studying their essays, I have discovered some of the devices and methods which allow the successful transference of technical or scientific information to a general audience.

One thing that many writers do is focus on their audience. They are writing for people with little scientific background, and they do tend to foreground these people in their writing process. For example, Freeman Dyson said that in writing his autobiography, Disturbing the Universe, "my sister was very much in my mind the whole time. She is my best critic anyway, and she was the one I sent chapter by chapter as it was written. She is also sort of

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typical of the audience I had in mind. She is an English lady of sixty who has no understanding whatever of science. But she's generally very intelligent. She helped a great deal. She would tell me when things went over her head and became dull." Other writers also relied on family members to provide a response from outside the scientific community. Harold Morowitz turns to his children: "my daughter knows no science formally. She's a lawyer with no experience in science. She is very good for comments. She and my youngest son, who is in drama, are good for bouncing ideas off of to see if I have really gone too far with the jargon." Other writers relied on their wives to bring a humanist perspective and understanding in critiquing their essays. Roger Swain's wife is a Renaissance historian specializing in the history of the family. He reads his work out loud to her as part of his composing process. "I will read bits and pieces aloud to my wife. By the time I get to the end of an article, my wife has heard it all several times." Lewis Thomas describes his wife as an avid reader who "remembers everything she reads," and whose interests include Jane Austen, George Eliot, Marcel Proust, English, French, and Scottish history, and the Restoration poets (YS 234-235). Thomas said that "I show [the essays] to my wife. She's a great unconscious editor. Whether it's working or not I can tell by the way she's reading it. I rely entirely on her." This deliberate seeking out of audiences indicates that the writers understand the need for audience adaptation. All of them

were concerned that the information they presented be clear and understandable but also enjoyable and significant to the readers.

Another way the authors' foregrounded concern for audience is the attention they paid to the adage often given to non-fiction writers: "Never underestimate your reader's intelligence or overestimate their knowledge." Several of the people I interviewed repeated this maxim and said they recalled it at various times while writing. It truly is a standard they judge their essays against. Also all of them were quite aware of the need to avoid jargon or define it if used. In fact, some of them said that was the major difference they perceived in their popular writing and their scholarly writing. Stephen Jay Gould said, "if there is any key to my essays, it's that there is no dilution of intellectual content. That is, I write about the exact same things I would write about if I were writing for my most rarified professional colleagues. I just use a different language. I don't use jargon; I define terms. But I think there is no reason to dilute the intellectual content at all."

Examination of the essays themselves reveal a variety of stylistic and rhetorical devices which are used to interest and entertain the reader, explain information, and also sometimes to assert the reason why a reader should be interested in the information contained in the essay. Jeremy Bernstein said that "the great recent discovery is that scientists are human beings," and that one of the devices he uses is that "most of the writing

that I do about science in one way or another gets people into it pretty quickly, and so that from time to time I can go back to describe these people. In other words, if I were to take a very complicated subject, whether it's atomic fusion or whether it's Goedel's theorem, and simply produce a popular essay on it, then I don't think that would in most cases hold the reader's attention, so I try to do these things in the context of some person or persons. I think that's more interesting for the reader.'

Bernstein and Gould use the idea of biography most extensively as a means of interesting the reader. For example, in order to explain the contemporary age of quantam physics, Bernstein profiles I. I. Rabi. He uses the life of Trofim Denisovich Lysenko to describe genetic research in the twentieth century as well as sound the cautionary note that "every country has its potential Lysenkos, entirely too willing to convert intellectual debates over controversial and difficult issues into denunciations of the 'enemies of the people'" (ES 141-142). Gould uses much of Darwin's life as a backdrop for discussing his evolutionary theory. He also frequently focuses on scientists outside the mainstream of scientific thought such as J Harlan Bretz and Randolph Kirkpatrick to demonstrate how the scientific method produces insight and knowledge.

But even more than biography, the writers use autobiography to add a human element into their science writing which also allows them to inject or rely on their professional ethos. Many of

the essays involve a personal anecdote that begins the essay or supports the main idea. Often the process of how the writer arrived at the idea is given prominence. Lewis Thomas in "The Lives of a Cell" writes: "I have been trying to think of the earth as a kind of organism, but it is no go. I cannot think of it this way. It is too big, too complex, with too many working parts lacking visible connections. The other night, driving through a hilly, wooded part of southern New England, I wondered about this. If not like an organism, what is it like, what is it mos_ like? Then satisfactorily for that moment, it came to me: it is most like a single cell." (LC 5). Stephen Jay Gould frequently begins his essays by recounting the incident that led him to the subject:

> When I was 10 years old, James Arness terrified me as a giant predac-ous carrot in The Thing (1951). A few months ago, older, wiser, and somewhat bored, I watched its latest television rerun with a dominating sentiment of anger. I recognized the film as a political document, expressing the worst sentiments of America in the cold war: its hero, a tough military man who wants only to destroy the enemy utterly; its villain, a naively liberal scientist who wants to learn more about it; the carrot and its flying saucer a certain surrogate for the red menace; the film's famous last words--a newsman's impassioned plea to "watch the skies"--an

> invitation to extended fear and jingoism.
>
> Amidst all this, a scientific thought crept in by analogy and this essay was born. (ESD 113)

Harold Morowitz also uses this method in an essay entitled "Women's Lib and the Battle Against Entropy" although not as explicitly as Gould:

> There was no doubt about it; the flooring on the small outside porch was going to have to be replaced. It was rotting through from the bottom and presented a real hazard. One trip to the lumber yard and there I was, ripping up the rotted planks and thinking naturally enough about the second law of thermodynamics, which was creating so many jobs. There had been the corroded copper pipes in the kitchen, the dirty ceiling in the laundry, and now the side porch. The universe was clearly and unmistakably moving downhill.
>
> A bit of reflection brought to me the sudden realization of how many of life's activities are directly tied up with our unending effort to slow down the increase of disorder in the immediate surroundings. (WL 56).

The use of personal anecdotes and autobiographical detail demonstrates clearly that scientists are human and do relate to the world in human ways. The use also demonstrates the particular

thought processes the writer went through--which to some extent mitigates the view of science and scientists as depersonalized. Morowitz's example also provides a justification for the reader to learn more about the second law of thermodynamics. If someone familiar with it automatically thinks of it when confronted with disorder, perhaps understanding it will help the reader understand disorder.

Another way the writers appeal to the readers is through the use of pronouns. Direct address in the form of 'you' is sometimes present. Thomas uses it in: "If you fly around the earth and keep looking down, you will see that we have inserted ourselves everywhere" (MS 108) and Swain in: "you can't read about bee pollen without encountering all sorts of diseases reputedly cured by eating it" (FD 140). In both of these instances, however, the "you" appears to be a more informal way of saying 'one' as well as a way of involving the reader. Sometimes the writer does specifically address the reader as Freeman Dyson does in the first essay of Disturbing the Universe where he describes his purpose and his audience. "I am talking here to unscientific people who ultimately have the responsiblility for guiding the growth of science and technology into creative rather than destructive directions. If you, unscientific people, are to succeed in this task, you must understand the nature of the beast you are trying to control. This book is intended to help you understand." (DU 5).

Another pronoun the writers use to appeal to the audience is "we" which enables the writer to create a community with the reader and allows the reader to not feel on the outside of the community of experts.

Another rhetorical strategy the writers use to make their essays appropriate to a general audience is to focus on a single specific example. I have already mentioned how Bernstein and Gould use individuals to achieve this strategy which is also used by Morowitz in "Helmholtz, Mayer and the M. D. Ph. D. Program" and Dyson in his discussions of Robert Oppenheimer and Matthew Meselson. Lewis Thomas uses it to discuss humans as social beings in "The MBL" and "Antaeus in Manhattan." He uses the Iks, an African tribe, to discuss general qualities of people. Roger Swain effectively uses the technique in his plea for the preservation of tropical rain forests in "Hamburgers and Houseplants." After reciting all the statistics about the destruction of rain forests, he writes:

> Boxcar statistics fail to capture the drama of felling even a single forest giant. As the chain saw begins to cut into a supporting buttress, spewing a plume of bright red sawdust, the parrots, the toucans, the oropendolous, and the howler monkeys who have been feeding in the tree's crown flee noisily. . . . The great tree joined by its neighbors crashes to the ground. It does not even

> bounce. When a tornado hits a cathedral, it is a tragedy. When such a tree falls, no one mourns. Whether its inhabitants are killed by the impact, or by desication, or incinerated in the fires that will shortly sweep through is unimportant.
>
> Who knows what new medicines are being consumed by the flames, what oils, resins, dyes, spices, and insectides; what unique genetic material that might someday be used for breeding; what plants that might someday grace our homes? (FD 198-200)

Giving a specific, concrete example helps move the technical, scientific information out of the abstract and into a realm where people can easily grasp it. Concrete examples also tend to be extremely persuasive.

Perhaps the most common type of rhetorical strategy which reveals audience adaptation is the use of comparison and contrast. Often by relating the scientific theory or concept to a more familiar one, the reader can understand it and accept it. The writers also use the strategy to refute commonly held ideas about science, scientists, or nature. Dyson uses H. G. Wells's book The Island of Doctor Moreau to discuss recombinant DNA research. Using references, quotations, and allusions from literature is another type of audience adaptative strategy employed by these authors. Dyson begins the essay by summarizing the salient parts of the story, namely that Dr. Moreau was trying to create a new

species of humanity. Dyson also demonstrates that as biology progressed so did the world envisioned by literature: "Huxley's Brave New World is only Moreau's Island enlarged and brought up to date by the addition of modern technology. Drugs replace whips and genetic programming replaces surgery" (DU 170). Dyson explicitly states that these images of scientists are the ones many people think of when issues of recombinant DNA research are raised: "The public sees, behind the honest faces of Matthew Meselson and Maxine Singer, the sinister figures of Doctor Moreau and Daedelus" (DU 178). The essay contrasts these fictional images of biologists with these two real biologists of extraordinary moral courage and insight. Matthew Meselson, professor of biology at Harvard, worked between 1963 and 1968 to get the U. S. to unilaterally agree to abandon "all development of biological weapons, [to destroy] our weapons stockpiles and [to convert] our biological warfare laboratories to open programs of medical research" (DU 175). Dyson's encomium is "seldom in human history has one man, armed only with the voice of reason, won so complete a victory" (DU 176). Dyson also points out that it was Maxine Singer, a molecular biologist, who "published a statement calling attention to the [public health] danger, soon after the first [recombinant DNA] experiments were done" (DU 177-178). Dyson's contrast asserts that biologists are aware of the danger and moral implications of their work and that they want certain

safe-guards so that as he quotes Meselson, "'a deep knowledge of life processes must be used only to reinforce what is essentially human in us'" (DU 178). The contrast acknowledges the public's perception and even justified concern, but Dyson is able to somewhat mitigate that concern by demonstrating the moral intergrity of biologists.

The qualities inherent in science as well as scientists are demonstrated by comparison and contrast. Lewis Thomas in "Alchemy" discusses and defines alchemy and its place in the development of the hard sciences. He points out that alchemy was belittled and attacked in its day, but that it did lead to the development of important scientific principles and even scientific methodology. He then compares the current state of scholarship in the social sciences to alchemy, pointing out that they also frequently suffer from belittlement and attack: "We do not acknowledge as we should the differences between the various disciplines within behavioral research--we speak of analytical psychiatry, sociology, linguistics, economics, and computer intelligence as though these inquires were all of a piece, with all "parties wearing the same old comical conical hats" (LNT 33). He concludes though by recognizing the triumph of alchemy and hopes that the same will hold true for behavioral research: "We will be looking back at today's social scientists, and their close collegues the humanists, as having launched the new science in a way not all that different from the accomplishement of the old

alchemists, by simply working on the problem--this time, the fundamental, primal universality of the human mind" (LNT 34).

Comparisons are also used to describe the principles of nature. Swain in explaining why microbes produce toxic chemicals writes: "On the other hand, if the invading fungus can quickly render the fruit unpalatable, then the fungus can grow and reproduce at leisure. The approach is the same as that of a child presented with a plate of cookies, who quickly licks each one to guarantee that no one else will eat them before he has a chance" (EP 165-166). Harold Morowitz contrasts the search for the Loch Ness monster with the drive to save the great whales.

> What has bothered me about the time and effort spent on searching for this phantom being is that it ignores some very profound biological principles. Individuals do not exist in isolation. The proper ecological unit is not the solitary organism but the species. . . . The Loch Ness monster must either be a member of a living group or must be the last survivor of a taxon approaching extinction. If Nessie is a member of a viable species, there must be a critical number of relatives around. . . . Thus The New York Times was engaged in the journalistic sin of making biological news in Scotland while the real story lay in the oceans of the world where the

> populations of some species of giant whales were being reduced below the numbers where animals of this ecological type can maintain their numbers. (WL 64-65)

By contrasting Nessie and the whales, Morowitz explains that species go extinct as species long before the last survivor has been killed or dies.

Comparison also helps the writer explain abstract scientific ideas as Gould uses it in combination with other adaptative techniques in "Biological Homage to Mickey Mouse." He uses Mickey as a concrete example of a scientific principle. (See the illustration on the back of the bibliography.) He demonstrates that not only has Mickey's personality changed from being a "rambunctious, even slightly sadistic character" to a "creature who gave his name as a synonym for insipidity," but he also

> became progressively more juvenile in appeareance. (Since Mickey's chronological age never altered--like most cartoon characters he stands impervious to the ravages of time--this change in appearance at a constant age is a true evolutionary transformation. Progressive juvenilization as an evolutionary phenomenon is called neotony.) (PT 97)

With the instatiation of Mickey Mouse before the reader, Gould can discuss the elements of neotony in humans. He uses this description of Mickey's change "to note that his path to eternal

youth repeats, in epitome, our own evolutionary story. For humans are neotonic. We have evolved by retaining to adulthood the originally juvenile features of our ancestors" (PT 106). Gould goes on to remark on the profound implications this has had on human development:

> We are preminently learning animals, and our extended childhood permits the transfererce of culture by education. Many animals display flexibility and play in childhood but follow rigidly programmed patterns as adults. [Konrad] Lorenz writes . . . "The characteristic which is so vital for the human peculiarity of the true man--that of always remaining in a state of development--is quite certainly a gift which we owe to the neotenous nature of mankind."
>
> In short, we, like Mickey never grow up although we, alas, do grow old. (PT 106-107)

The example of Mickey Mouse helps make clear for the reader what neotony is which enables Gould to explain its relevance and demonstrate how we are like Mickey Mouse.

As this last example I hope demonstrates another characteristic strategy of audience adaptation is humor. Word play abounds in these essays also which helps make serious subjects light-hearted and non-threatening.

Since the writers do deliberately use strategies to adapt to

their audience, I asked them what influence they thought they could have on an audience and what they hoped to accomplish by writing about science for the general public. Several of them said that they hoped they could change public opinion about science and scientists. Gould said that he wrote about pluralism and controversy in science because people need to realize that because experts may be scientists "doesn't mean their opinions on the moral and ethical questions that are raised [by science and technology] are any better than anybody else's. And to have a participatory kind of society, you have to get that point of view across." Lewis Thomas uses his forum as a way of revealing "misperceptions of scientists that exist in the public mind that I would like to change. One of them is that science has acquired so much factual information and data that we're almost home with all the information we need for comprehending the world. . . . My position is that what has happened in this century . . . really has been the discovery of how little we know about nature. . . . I want people to know it's great fun to have a chance to look at it." Harold Morowitz wants to help people understand "what the process of science is--how information is obtained in science, how it is evaluated and used. I think this comes up just an enormous number of times in public issues." Freeman Dyson wants people to recognize about science "how varied it is, what an enormous variety of different things one can do and still be a scientist!" Roger Swain said that when he thought about what he was trying to

accomplish in writing:

> On my good days I think I'm shaping the world--that I can persuade a North American audience to dig deep into their pockets and shell out money to save tropical forests, that I can persuade people to clean up lakes. . . . In my more sober moments, I realize that I probably entertain first, that I'm instructive second, that I'm equipping them with information and facts with which to make judgements. Third, I'm probably piquing their social consciousness slightly, but very slightly.

Thus not only is the idea of audience important to these writers, but they believe that they have a message to convey which is important that the general public in the twentieth century have in order to deal with the world created by science.

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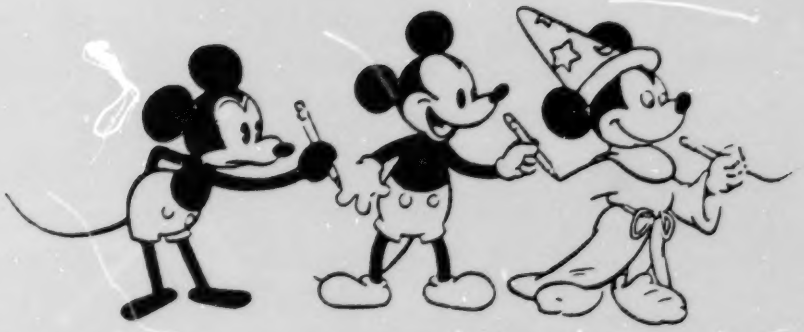

Mickey's evolution during 50 years (left to right). As Mickey became increasingly well behaved over the years, his appearance became more youthful. Measurements of three stages in his development revealed a

greater relative head size, larger eyes, and an enlarged cranium–all traits of juvenility. © Walt Disney Productions

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